# Gear-Bearing Technology

John Vranish

Technology Transfer Expo and Conference

March 3-6, 2003

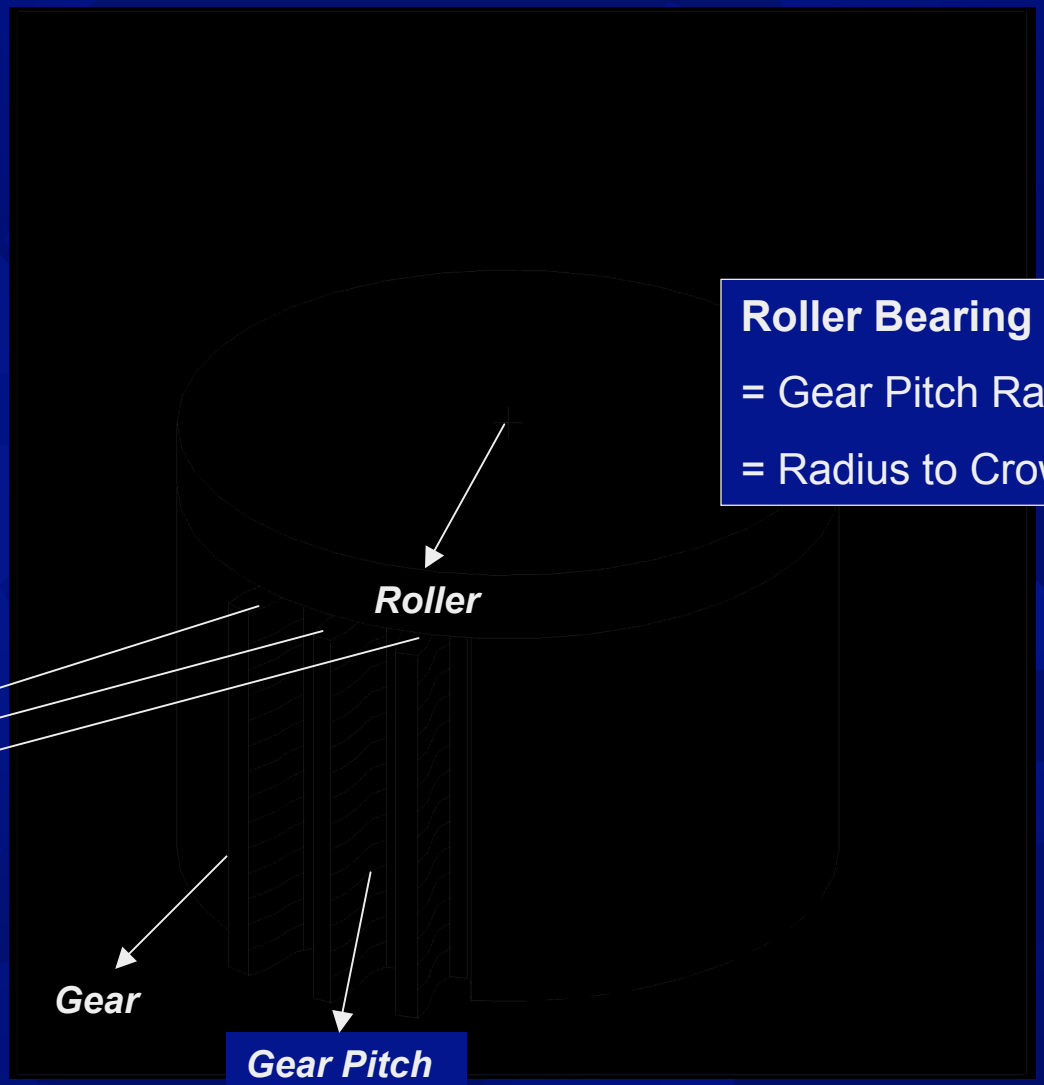
# Over-View: Gear-Bearings (Components, Devices, Architecture)

- Explained by describing critical steps in 4- year evolution.
- Started with NASA search for over-achieving planetary speed reducer.
- Successful completion pointed towards transferring technology to industry.
- Weaknesses emerged in satisfying industry needs.
- Solutions pointed to many new applications and motions beyond planetary transmissions.
- These new applications pointed to a larger pattern in mechanical engineering.
- As a pattern began to emerge for so many diverse kinds and sizes of applications, a new, superior mechanical architecture emerged.

# NASA's Search for Large Speed Reduction

## FIRST GEAR-BEARING COMPONENTS AND DEVICE (70:1 SPEED REDUCTION, 1.25 IN. DIA.)

# Gear-Bearing Roller Component



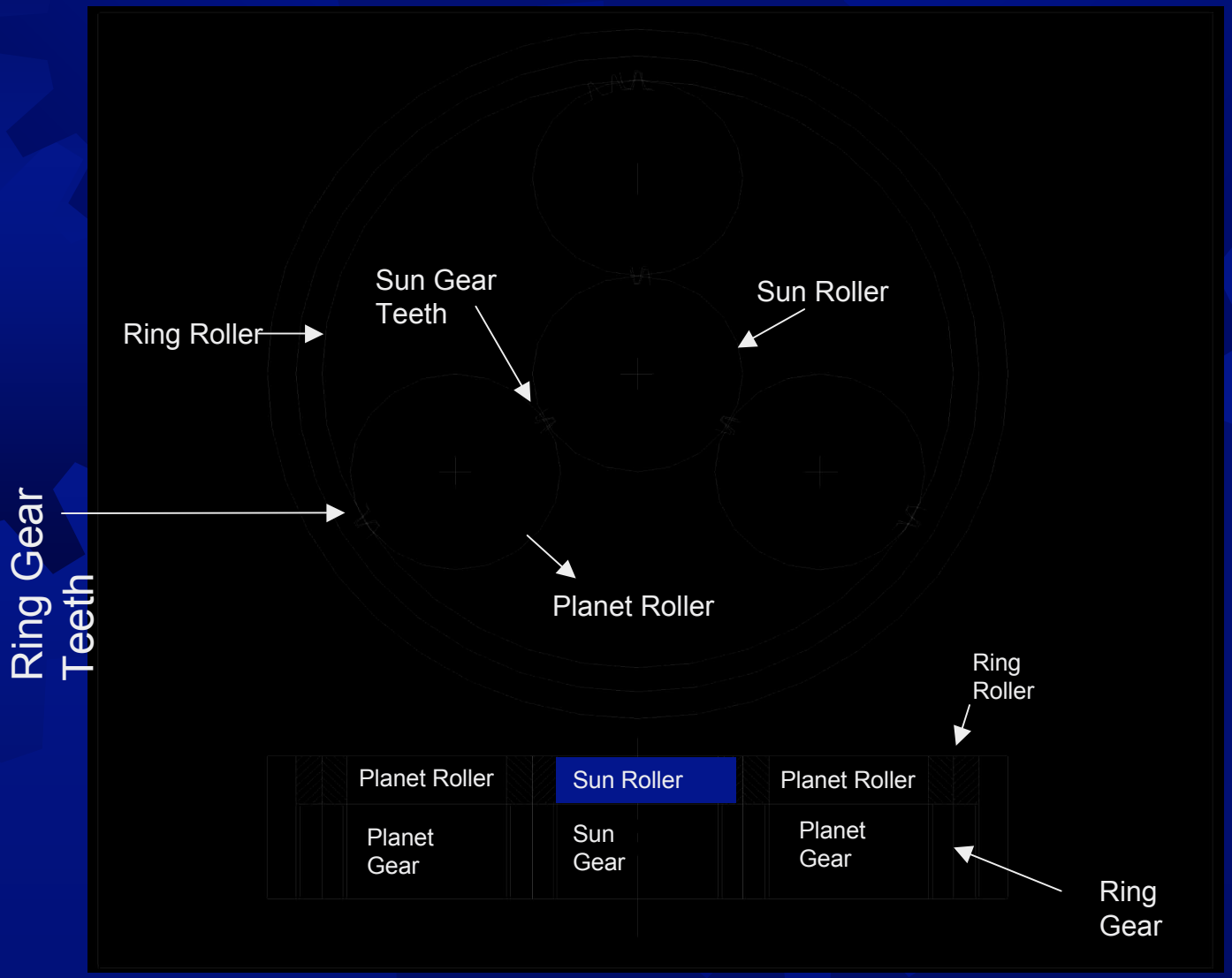

**Roller Bearing Radius**

= Gear Pitch Radius

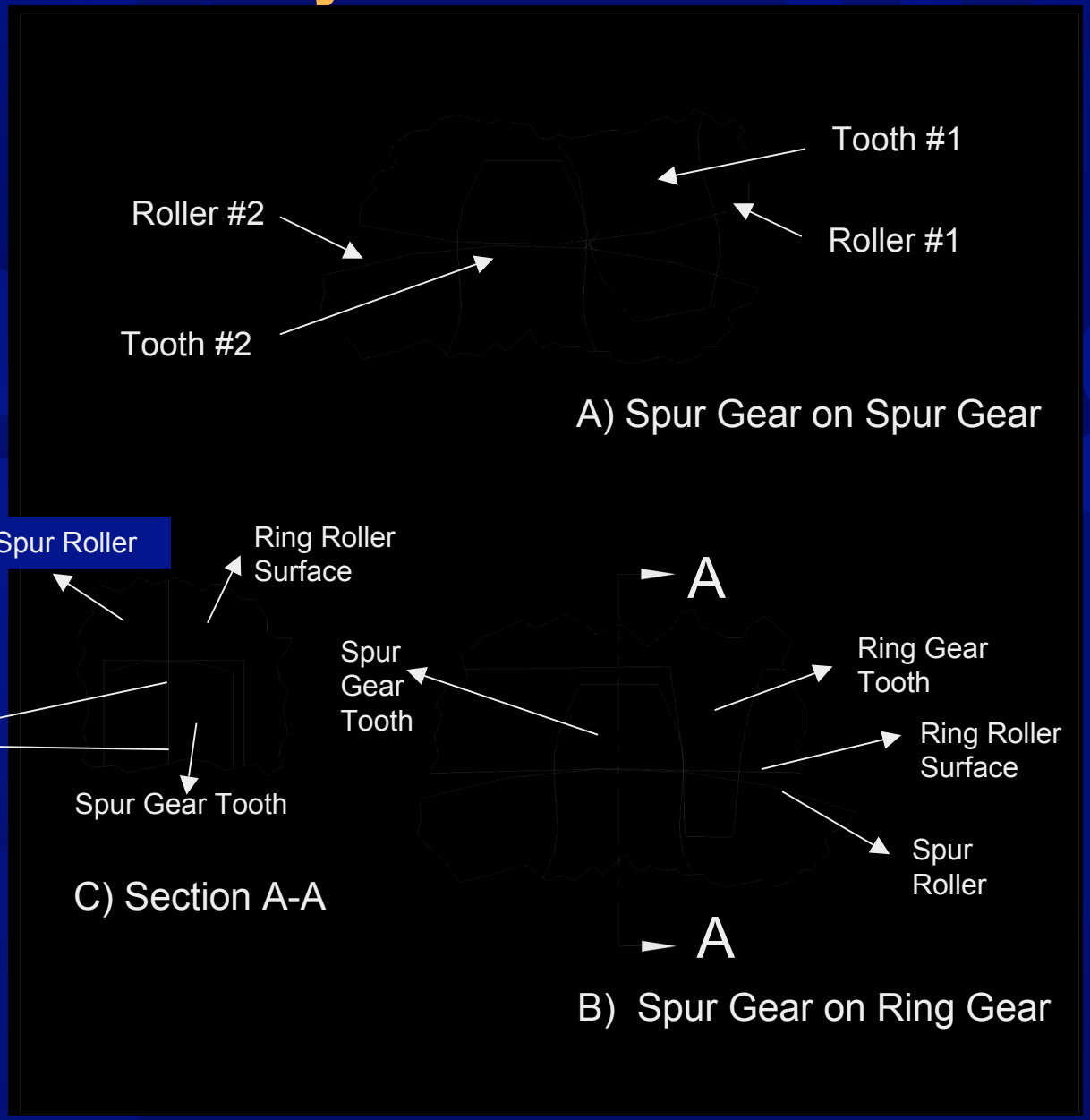
= Radius to Crowned Top

Crowned Tops of Gear Teeth

# Gear-Bearing Roller Stabilization Technique



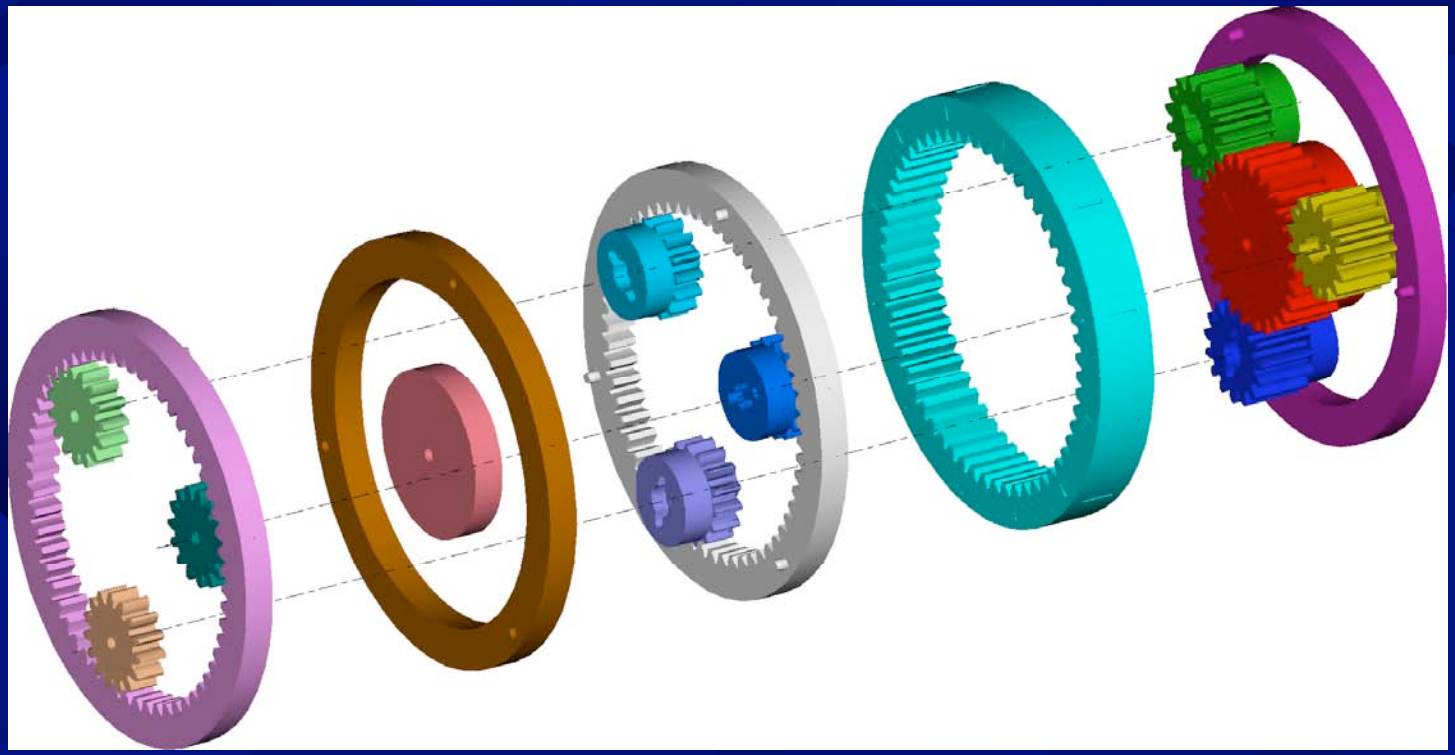
# Gear-Bearing Interlocking Force Synchronization



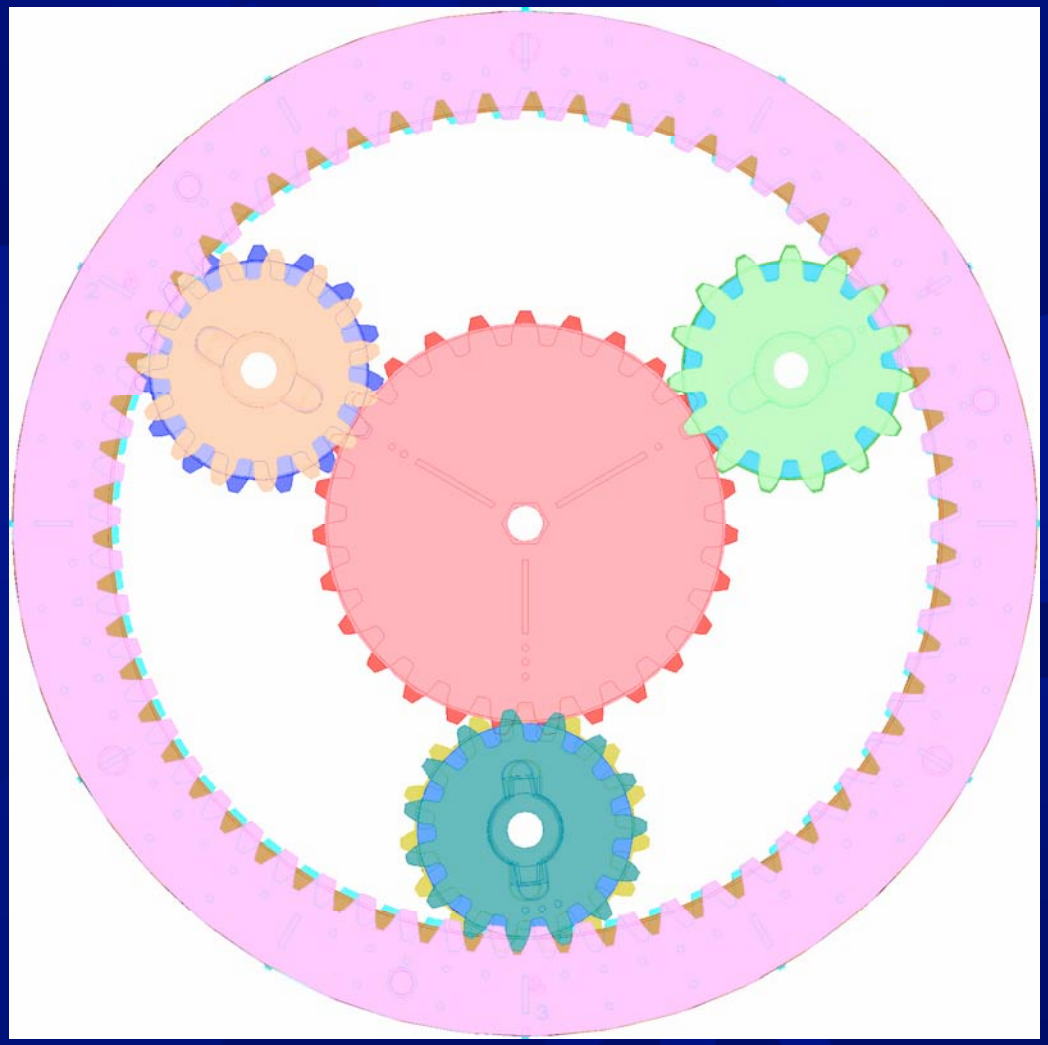
# NASA Search For Large Speed Reduction Continues

SINGLE-TOOTH DIFFERENCE GEAR-BEARING TRANSMISSION (325:1 SPEED REDUCTION, 1.25 IN. DIA.) FIRST USE OF PHASE-TUNED PLANETS

# Single-Tooth Working Rapid Prototype (185:1) (Uses Phase-Tuned Planets)



# Single-Tooth Working Rapid Prototype (185:1) (Uses Phase-Tuned Planets)




# Phase-tuning Provides Unexpected Benefits

(WHILE THE NUMBER OF TEETH IN THE GROUND RING AND SUN SHOULD BE DIVISIBLE BY 6)

- Number of teeth in output ring can be any number-great design flexibility.
- So multiple planets can be used for strength independent of speed reduction.
- And targeted super speed reductions are straight forward.

# Phase-Tuning Provides Targeted Super Speed Reduction

(For all Tables, bottom stage has 24 teeth in Sun, 21 teeth in Bottom Planet Half and 66 teeth in Ground Ring)

Table 1. Single Tooth Large Speed Reduction

| Output Ring | Planet Top | Speed Reduction |
|---|---|---|
| 1. 65 teeth (-1) | 21 teeth (same as Bottom) | -243.75:1 |
| 2. 67 teeth (+1) | 21 teeth (same as Bottom) | +251.25:1 |

Table 2. Super Large Speed Reduction

| Output Ring | Planet Top | Speed Reduction |
|---|---|---|
| 1. 69 teeth (+3) | 22 teeth (+1) | -1,811.25:1 |
| 2. 63 teeth (-3) | 20 teeth (-1) | +1,653.75:1 |

# Phase-Tuning Provides Targeted Super Speed Reduction (continued)

(For all Tables, bottom stage has 24 teeth in Sun, 21 teeth in Bottom Planet Half and 66 teeth in Ground Ring)

Table 3. Targeted Super Large Speed Reduction (goal of +/-500:1)

| Output Ring | Planet Top | Speed Reduction |
|---|---|---|
| 1. 57 teeth (-9) | 18 teeth (-3) | +498.75:1 (0.25% error) |
| 2. 76 teeth (+10) | 24 teeth (+3) | +498.75:1 (0.25% error) |
| 3. 78 teeth (+12) | 25 teeth (+4) | -511.88:1 (-2.38% error) |


# Successful Completion Pointed Towards Transferring Technology to Industry

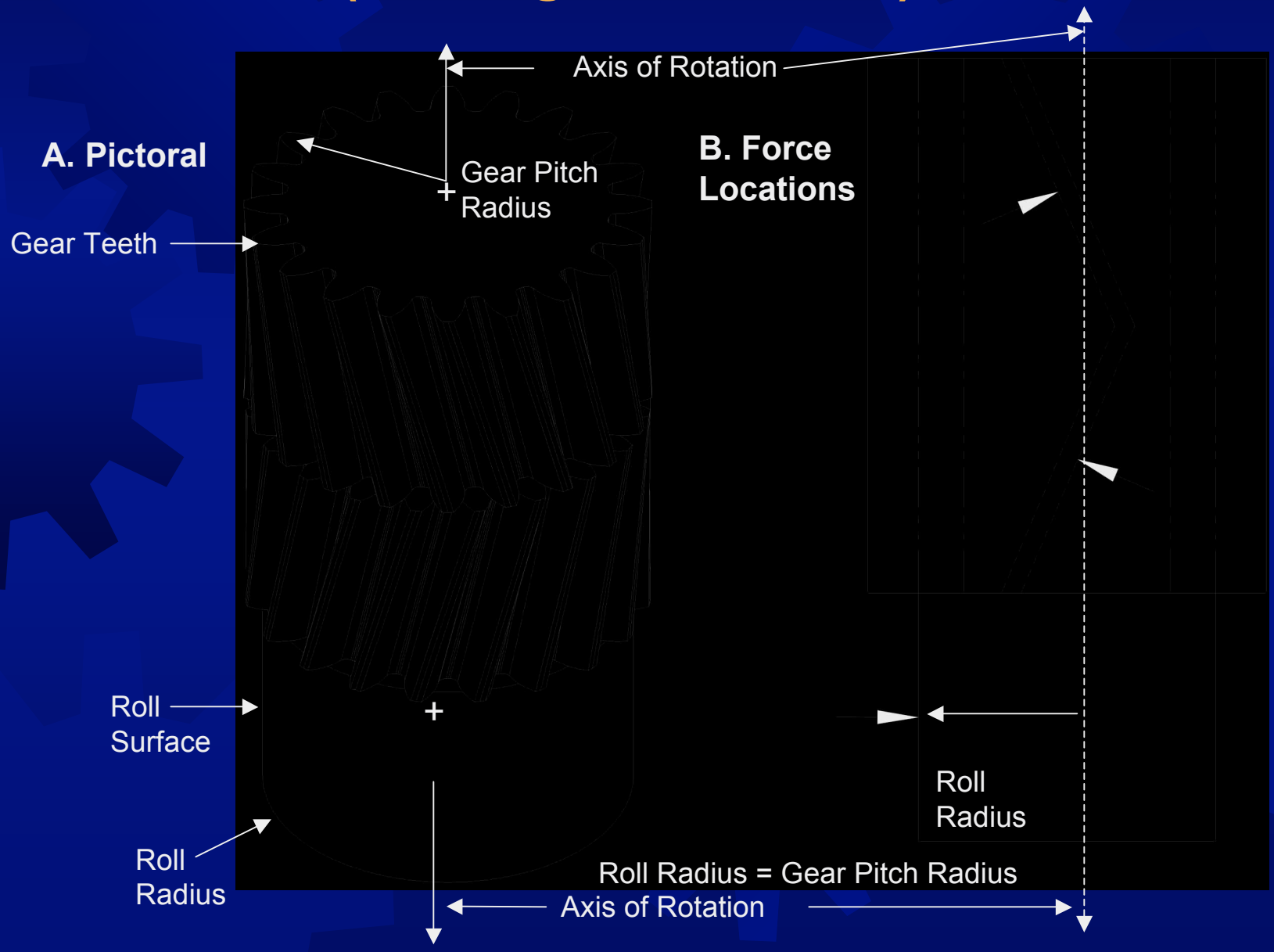
WEAKNESSES EMERGED IN SATISFYING INDUSTRY NEEDS.

- Thrust bearing point contact load limitation.
- Not anti-backlash.
- Industry needs both low and high speed reduction.

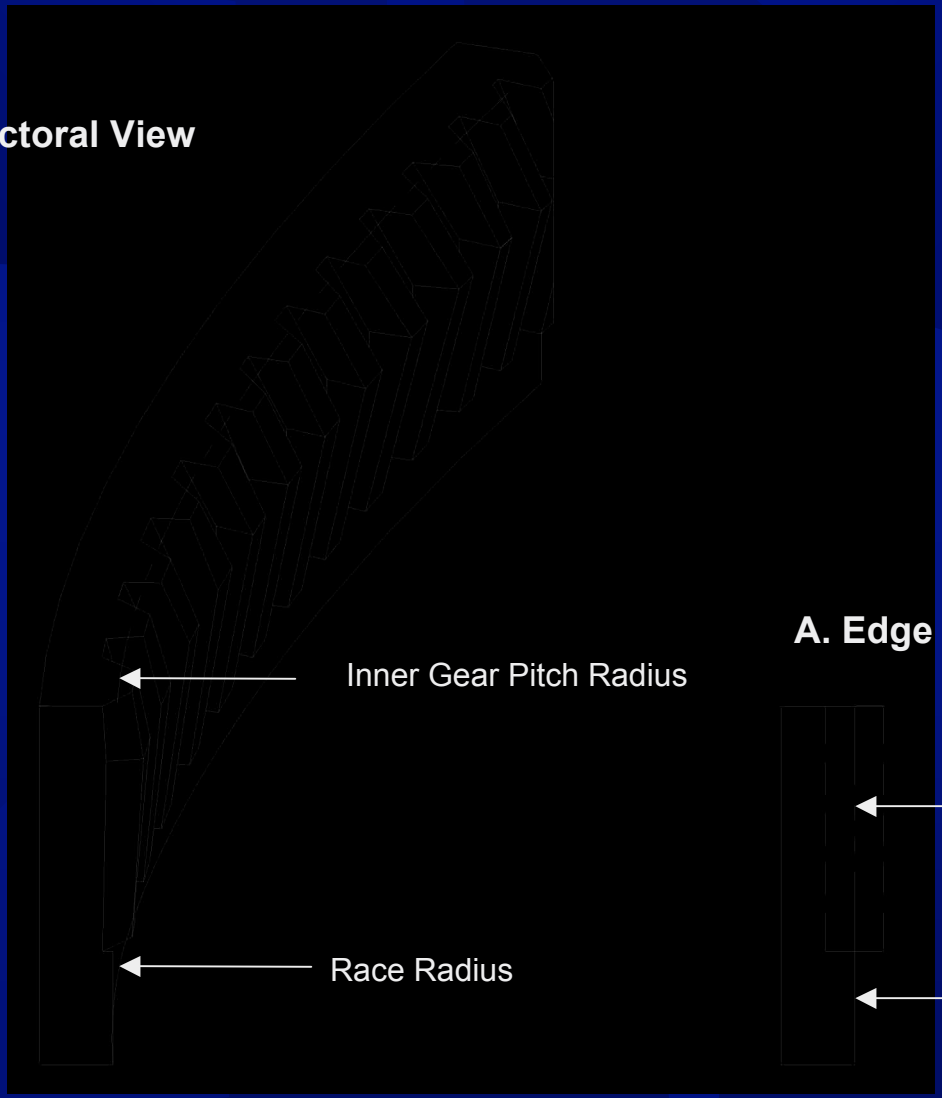
SOLUTIONS WERE FOUND.

- Helical gear teeth forms (including herringbone) give outstanding thrust bearing performance.
- Rifle true anti-backlash (proven out previously by NASA) applies in this case.
- Phase-tuning techniques work to provide low speed reduction.

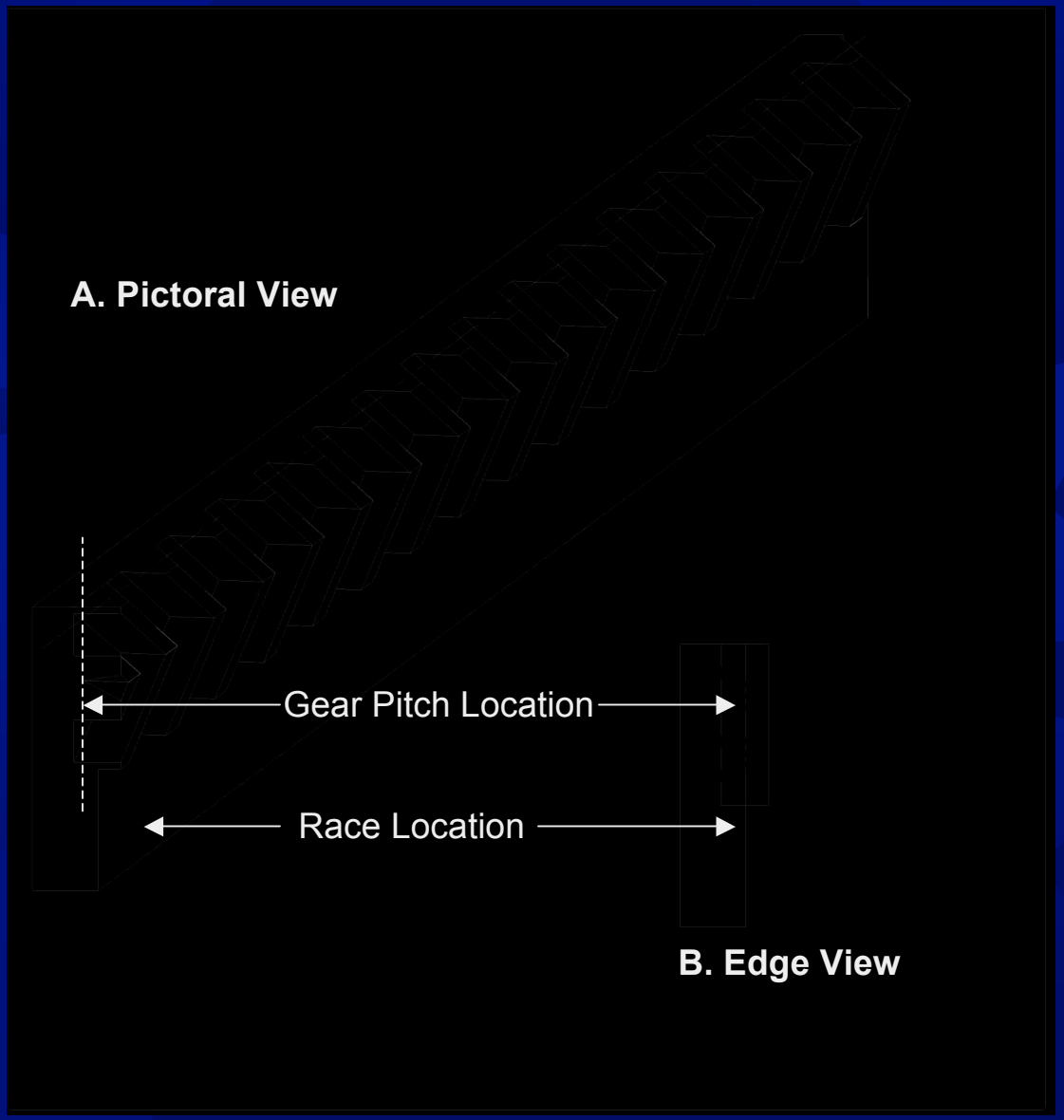
# Herringbone Gear-Bearing Rollers (Herringbone Planet)



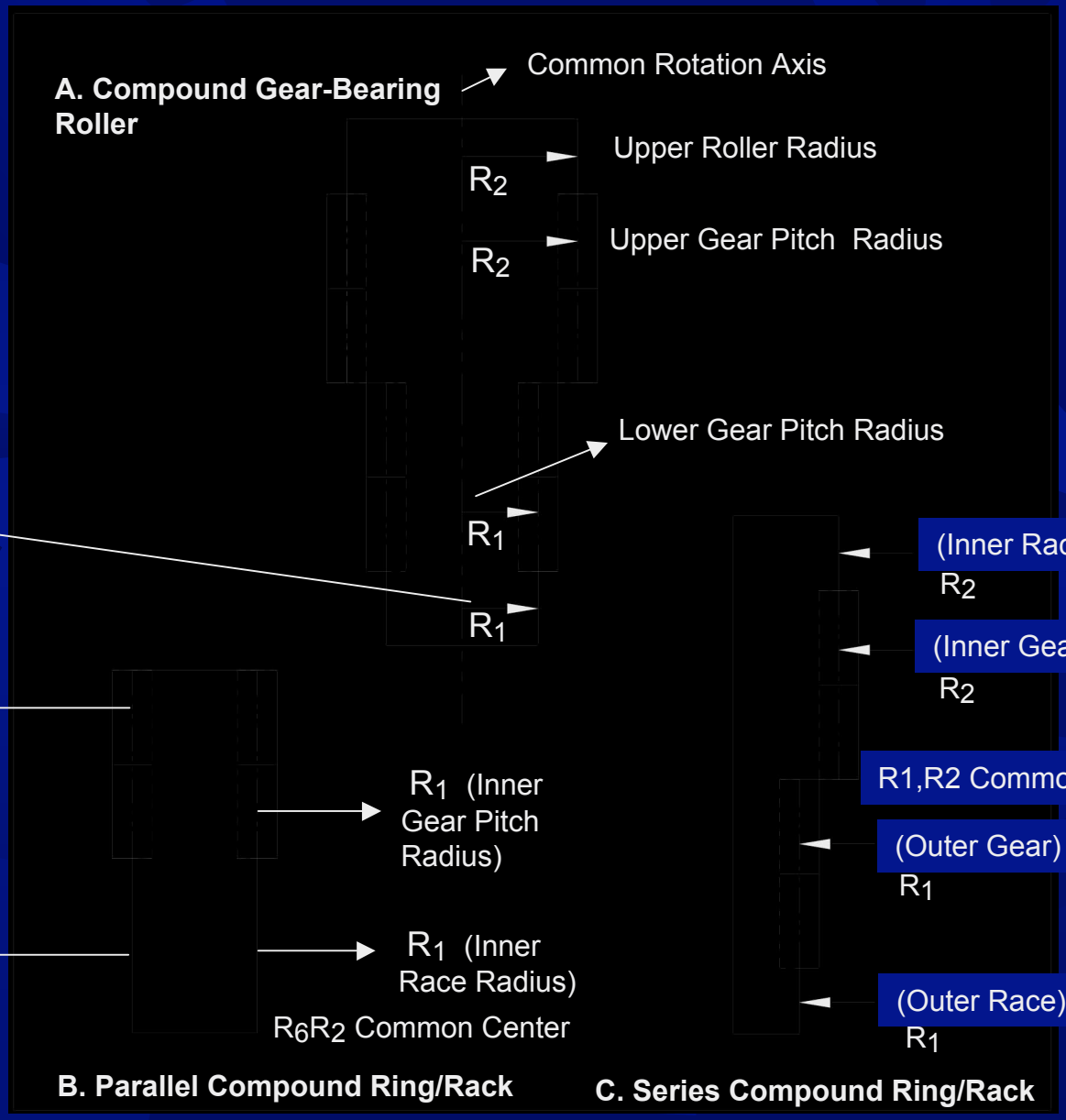
# Herringbone Gear-Bearing Inner Ring (Herringbone Inner Ring)



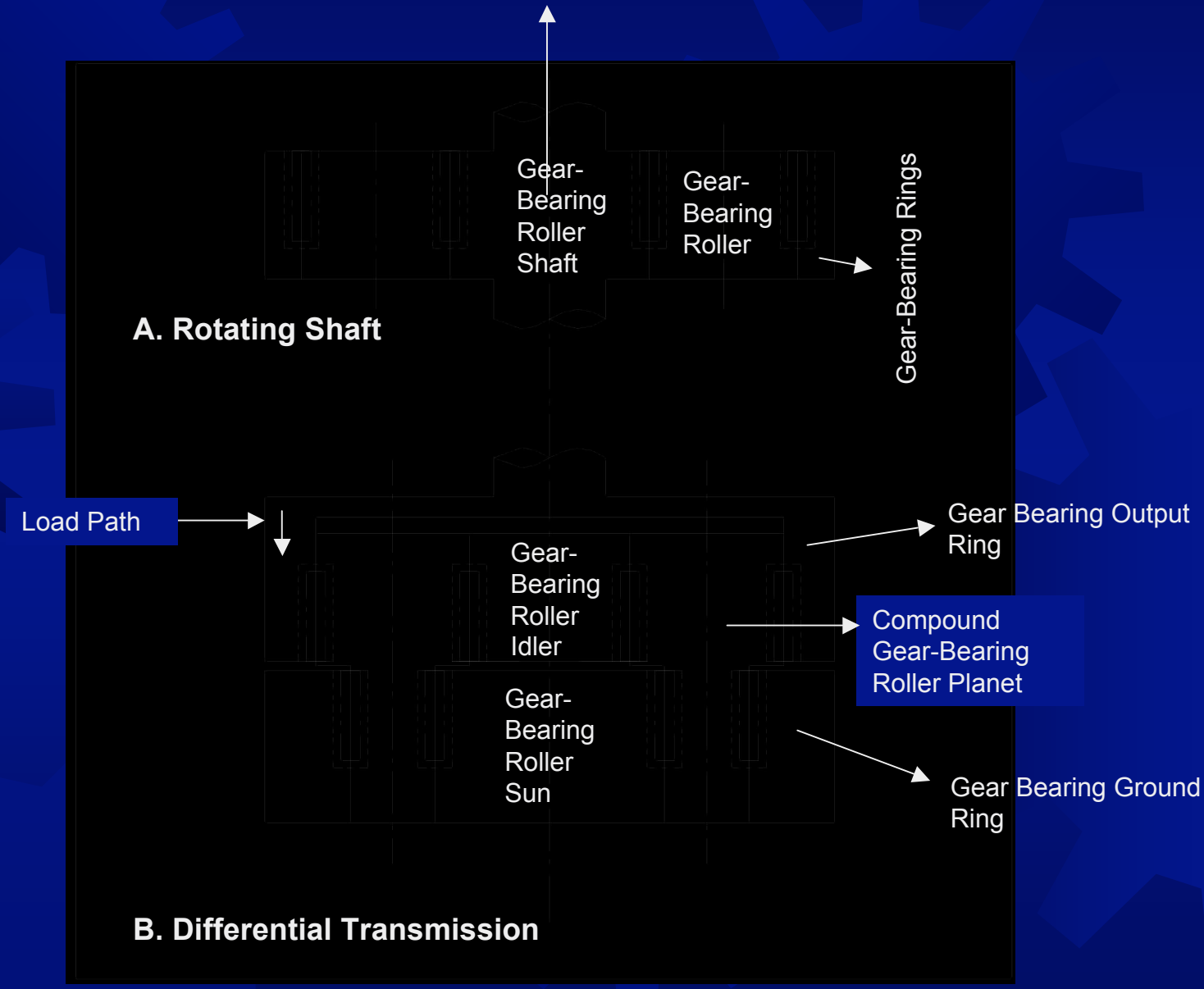
# Herringbone Rack



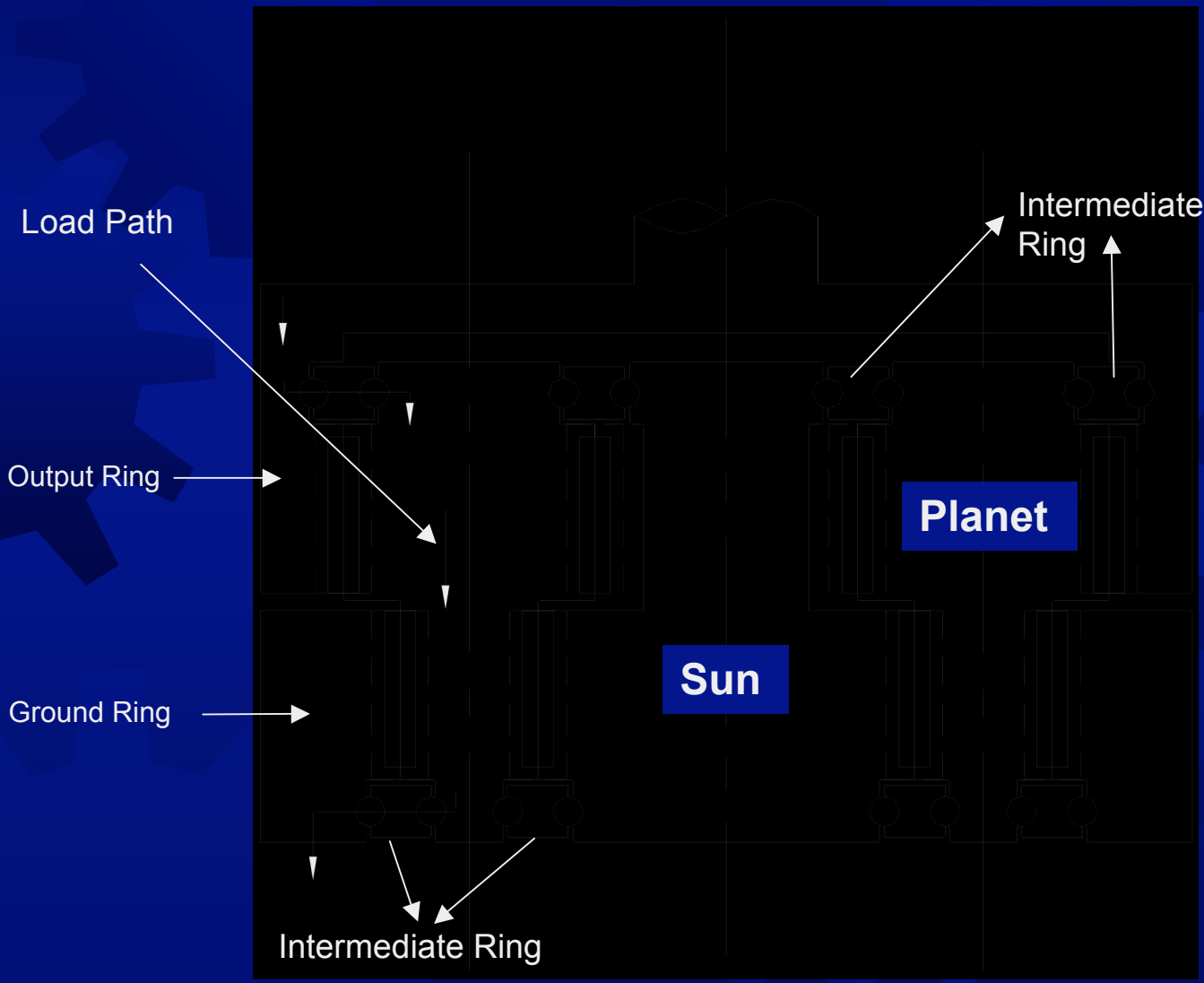
# Compound Gear-Bearing Components



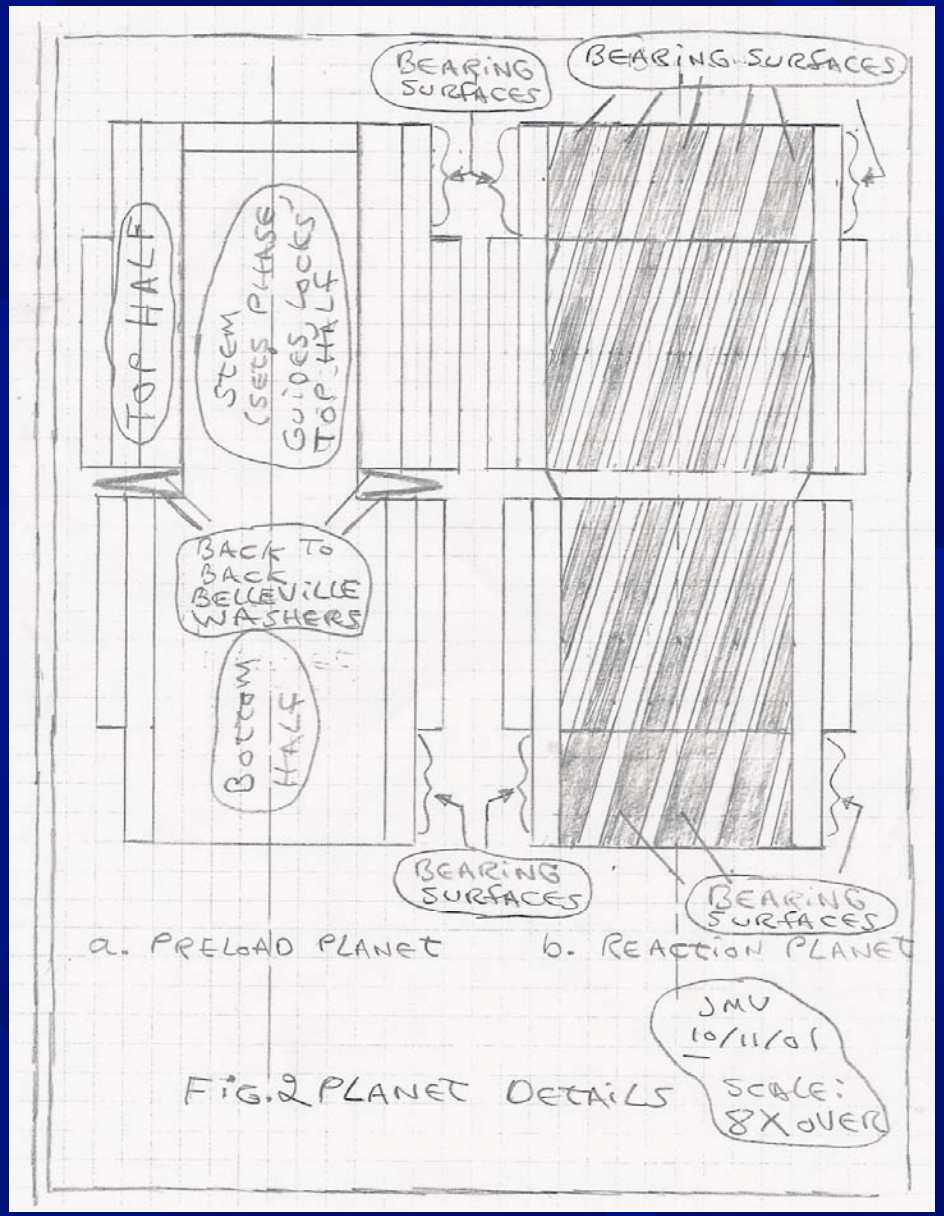
# Gear-Bearing Devices



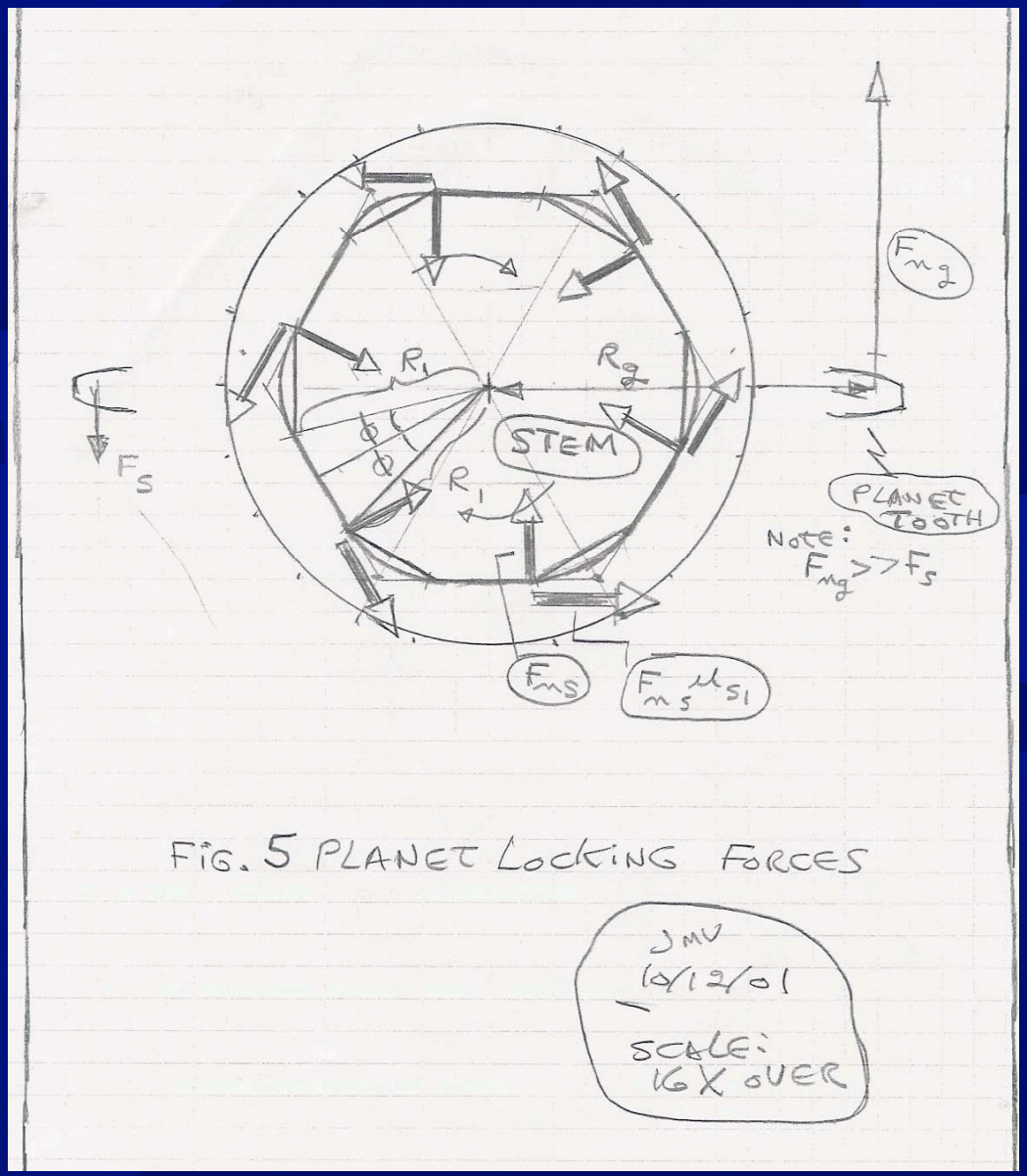
# Differential Transmission (Gears And Bearings)



# Rifle True Anti-Backlash Gear-Bearing Planets



# Rifle True Anti-Backlash Gear-Bearing Planet Friction Locking




# New Directions In Applications And Motions

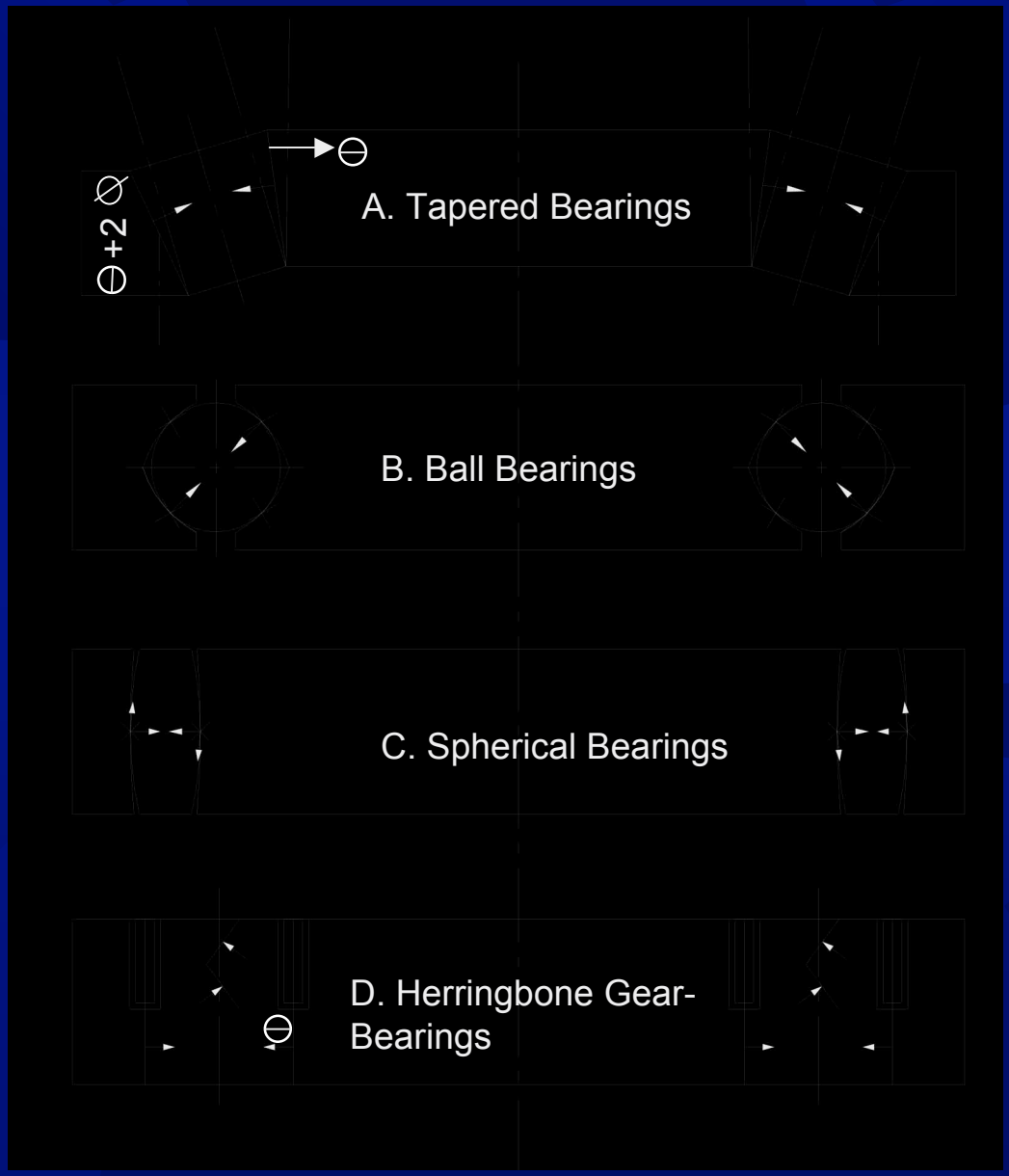
OUTSTANDING THRUST BEARING PERFORMANCE OF GEAR-BEARING HELICAL/HERRINGBONE TEETH SUGGESTS MAJOR ROLL IN BEARING APPLICATIONS.

- GEAR-BEARING ANTI-FRICTION ROTARY SHAFTS.
- GEAR-BEARING HIGH LOAD WHEEL BEARINGS.

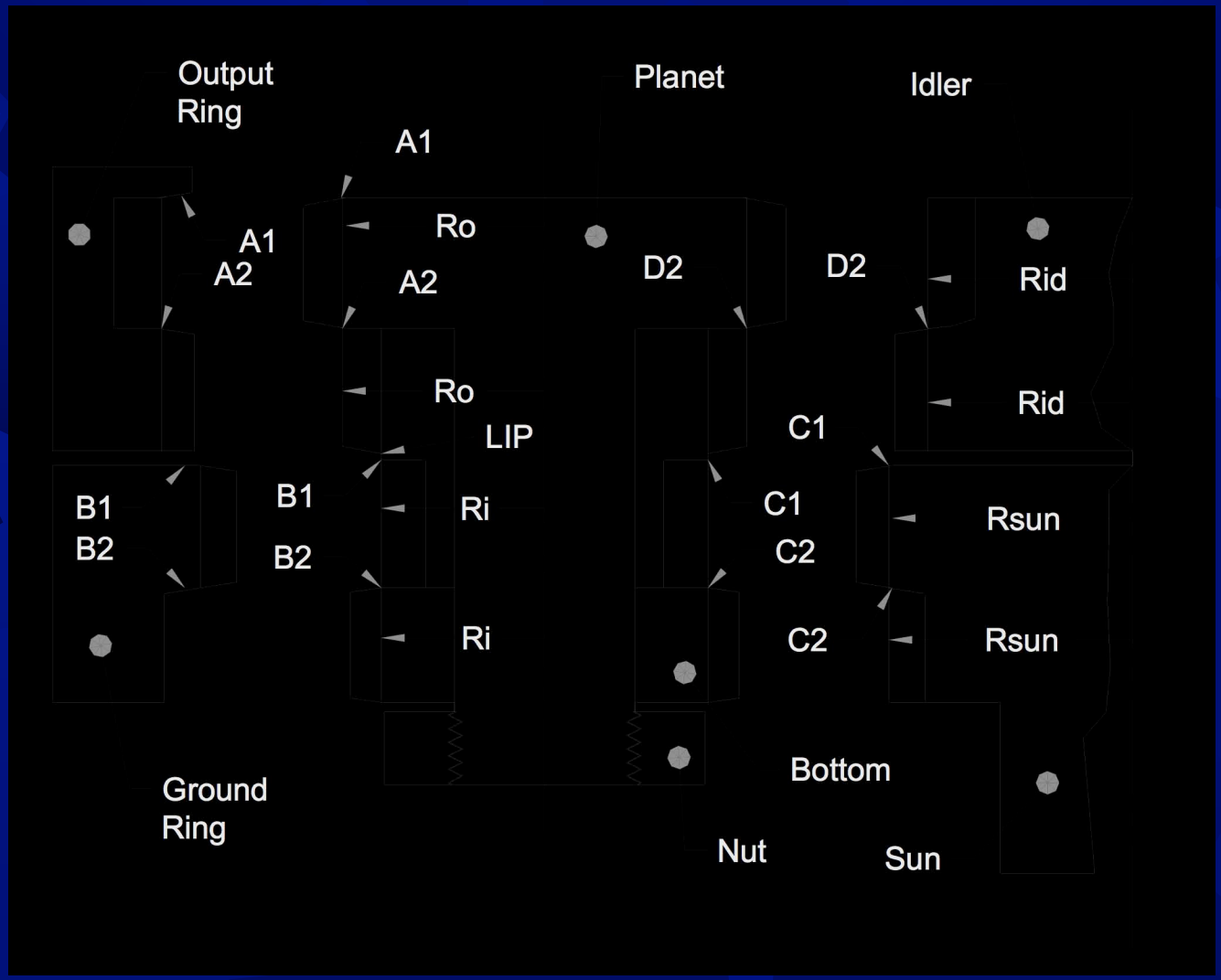
GEAR-BEARING APPROACH SEEMS GENERAL ENOUGH TO WORK WELL IN LINEAR SLIDES AND MOTION CONVERSION DEVICES.

- SIMPLE LINEAR SLIDES (BOTH MODERATE AND LONG STROKE).
- DIRECTION-REVERSING PAIRS OF LINEAR SLIDES.
- MOTION CONVERSION DEVICES

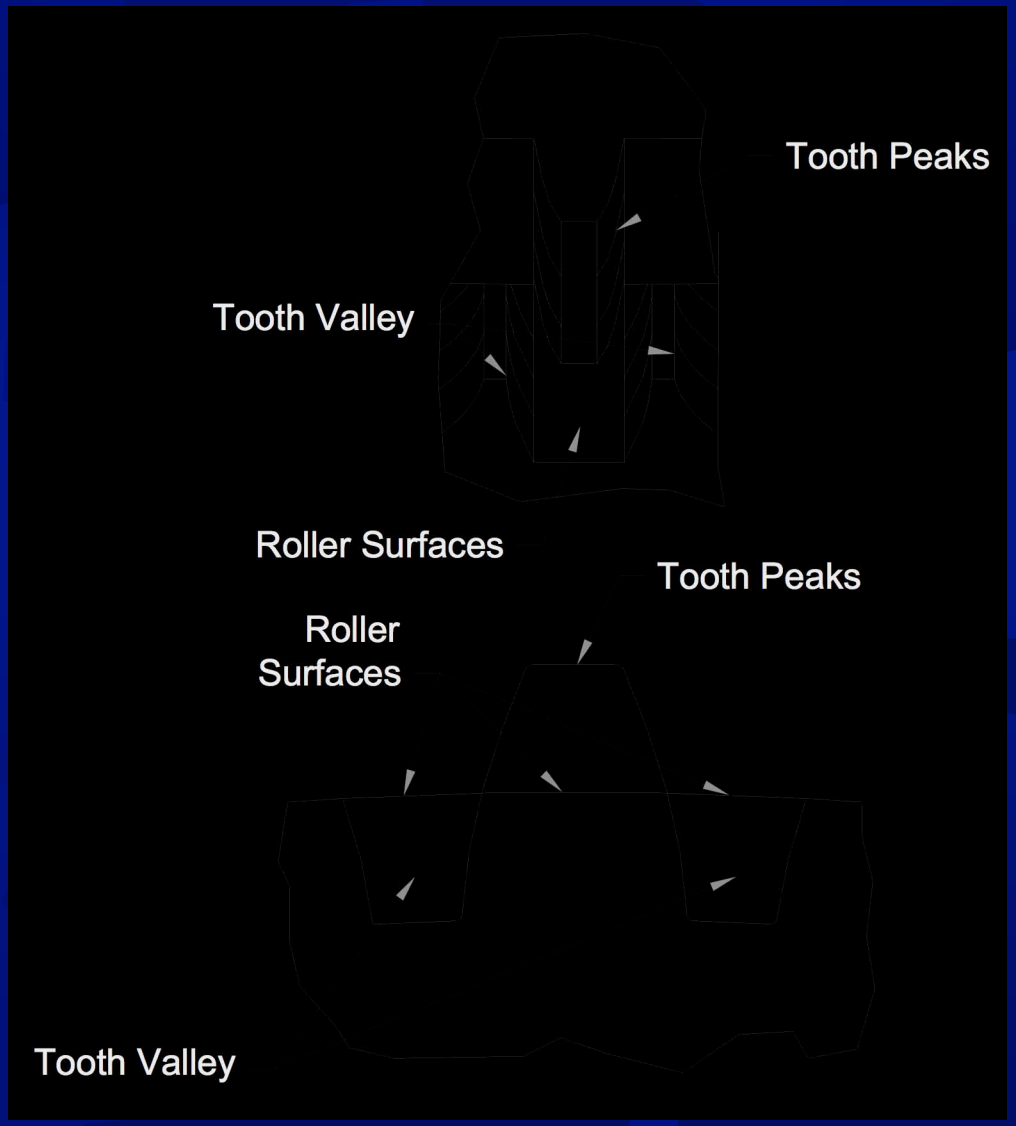
# Bearing Load Patterns



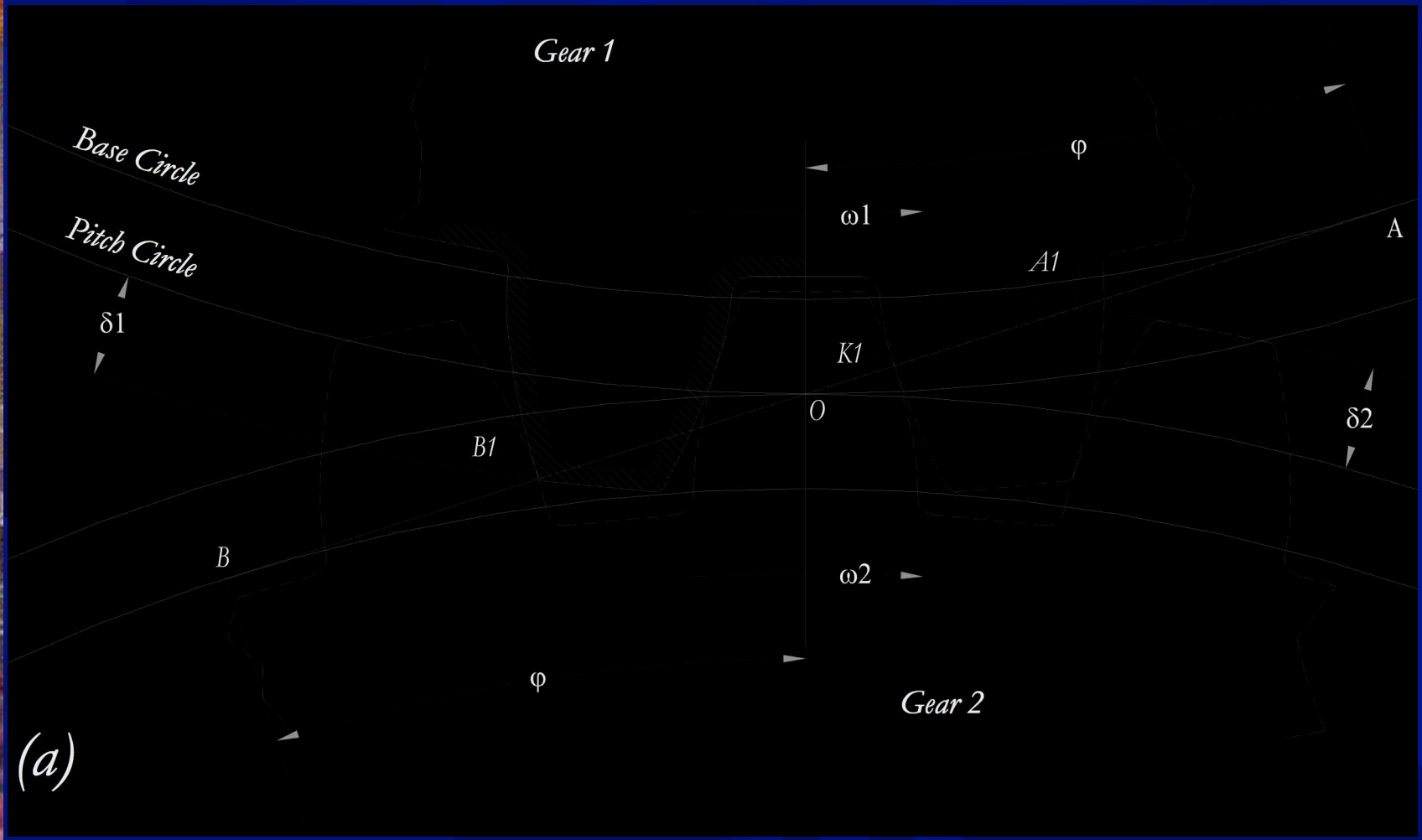
# Half Tooth Cross Section View



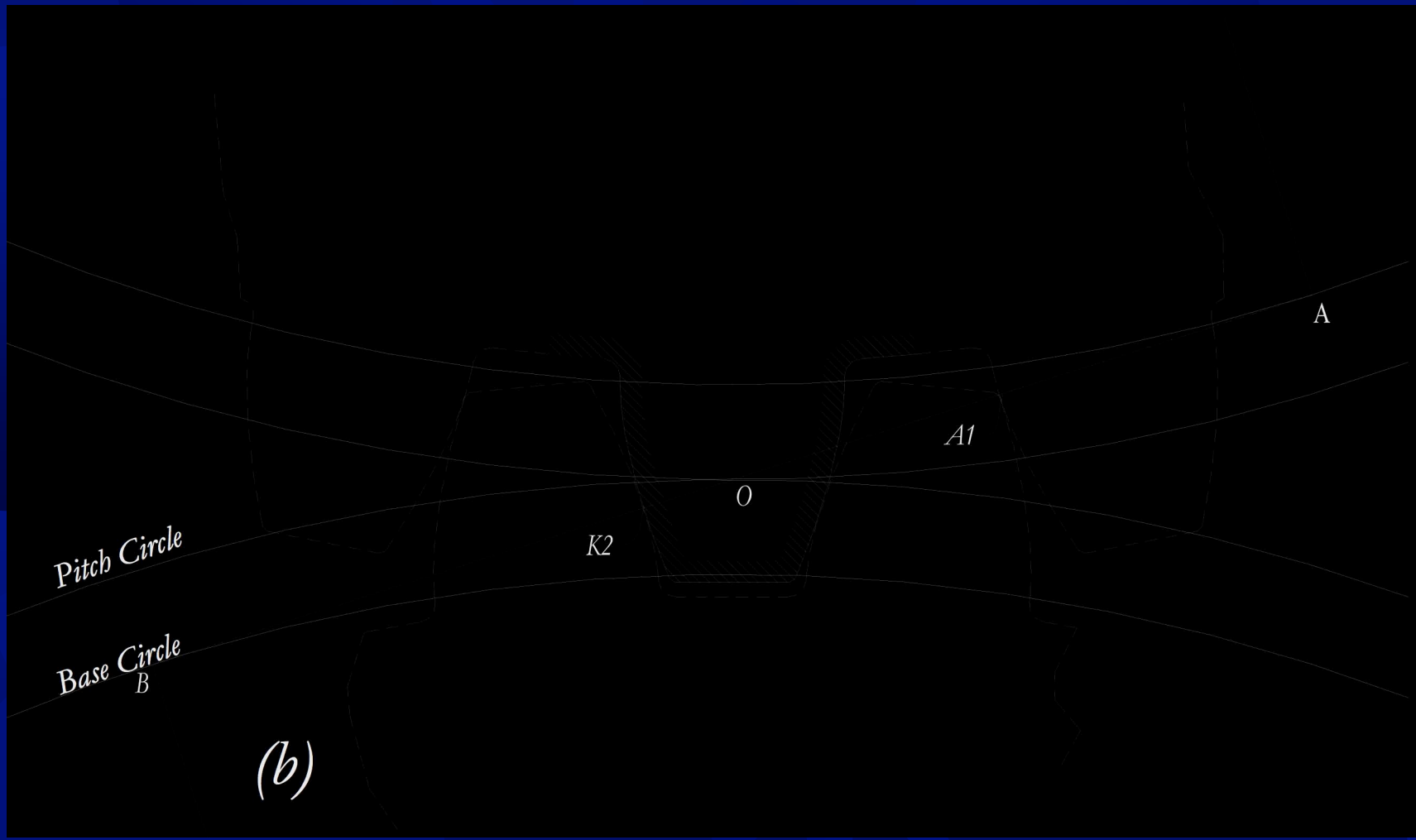
# Half Tooth Principle



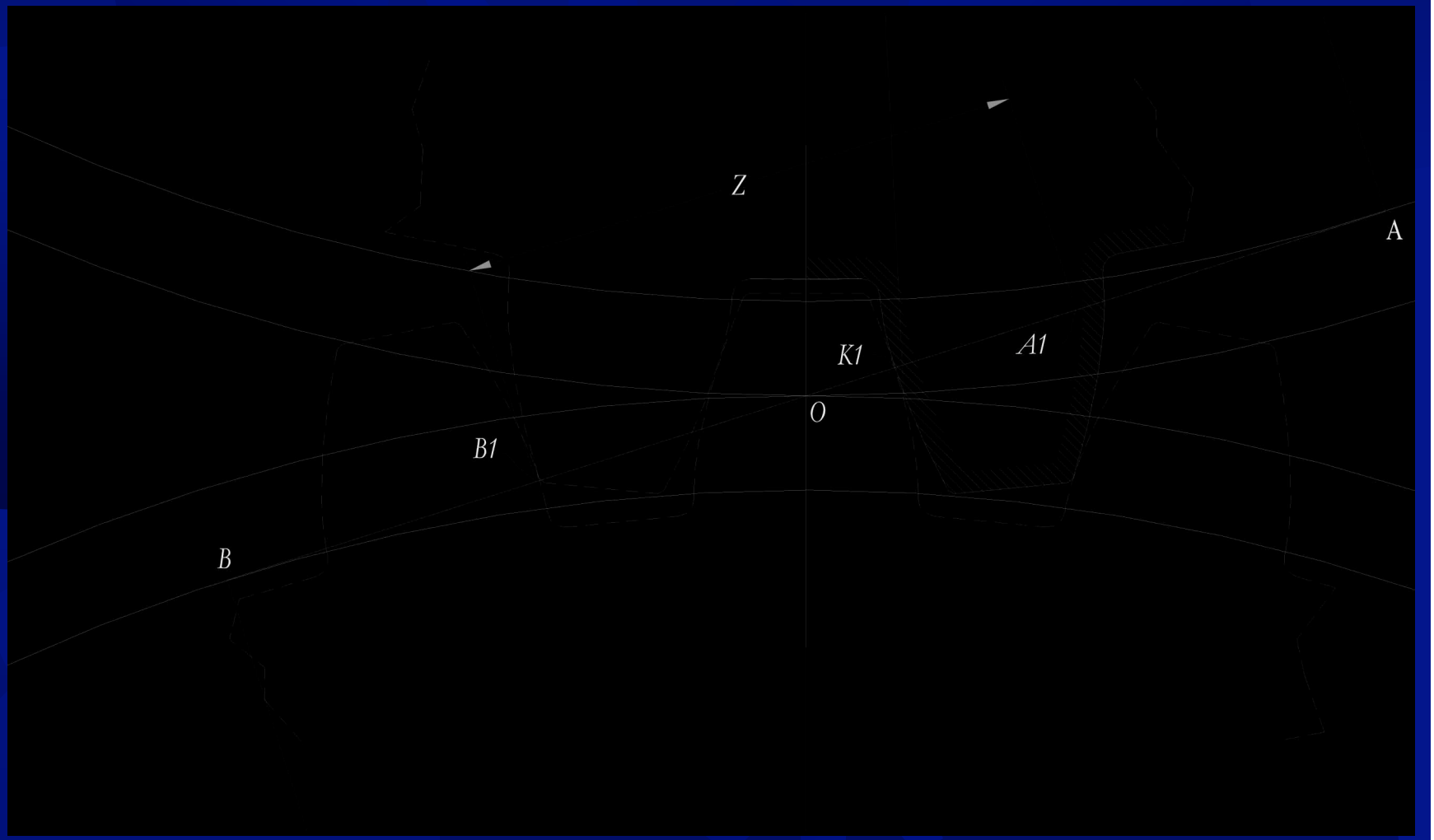
# Half Tooth Mesh Sequence



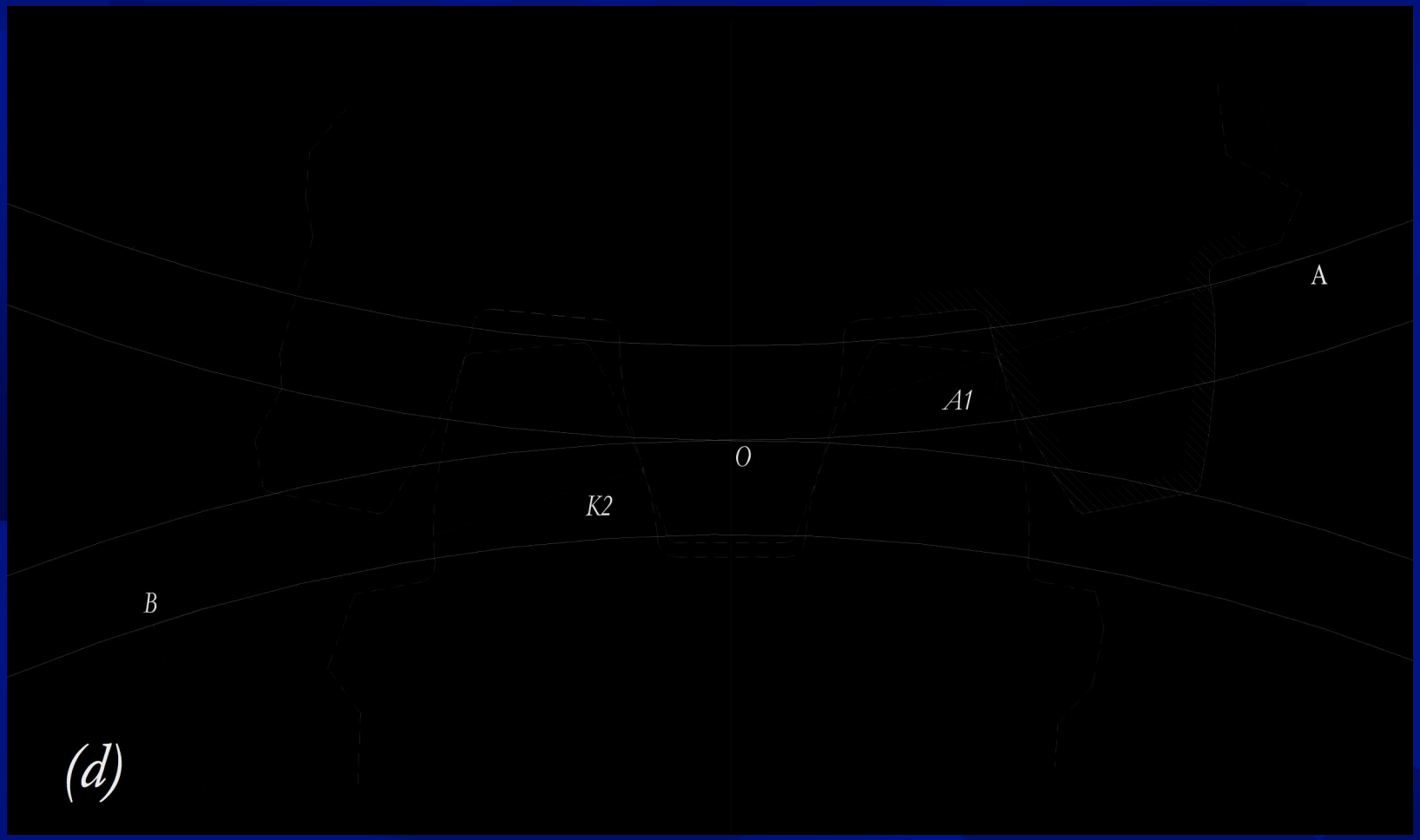
# Half Tooth Mesh Sequence



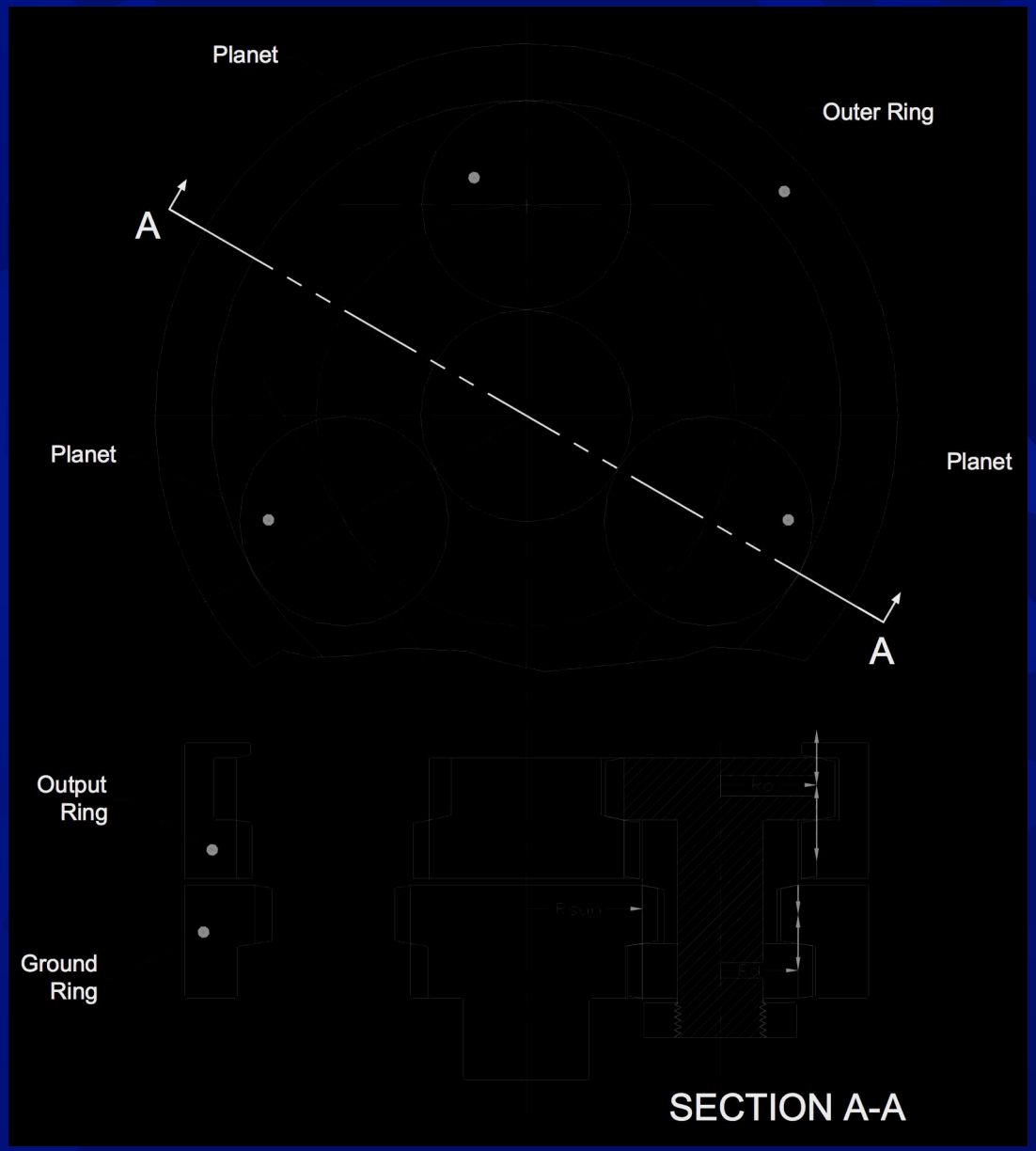
# Half Tooth Mesh Sequence



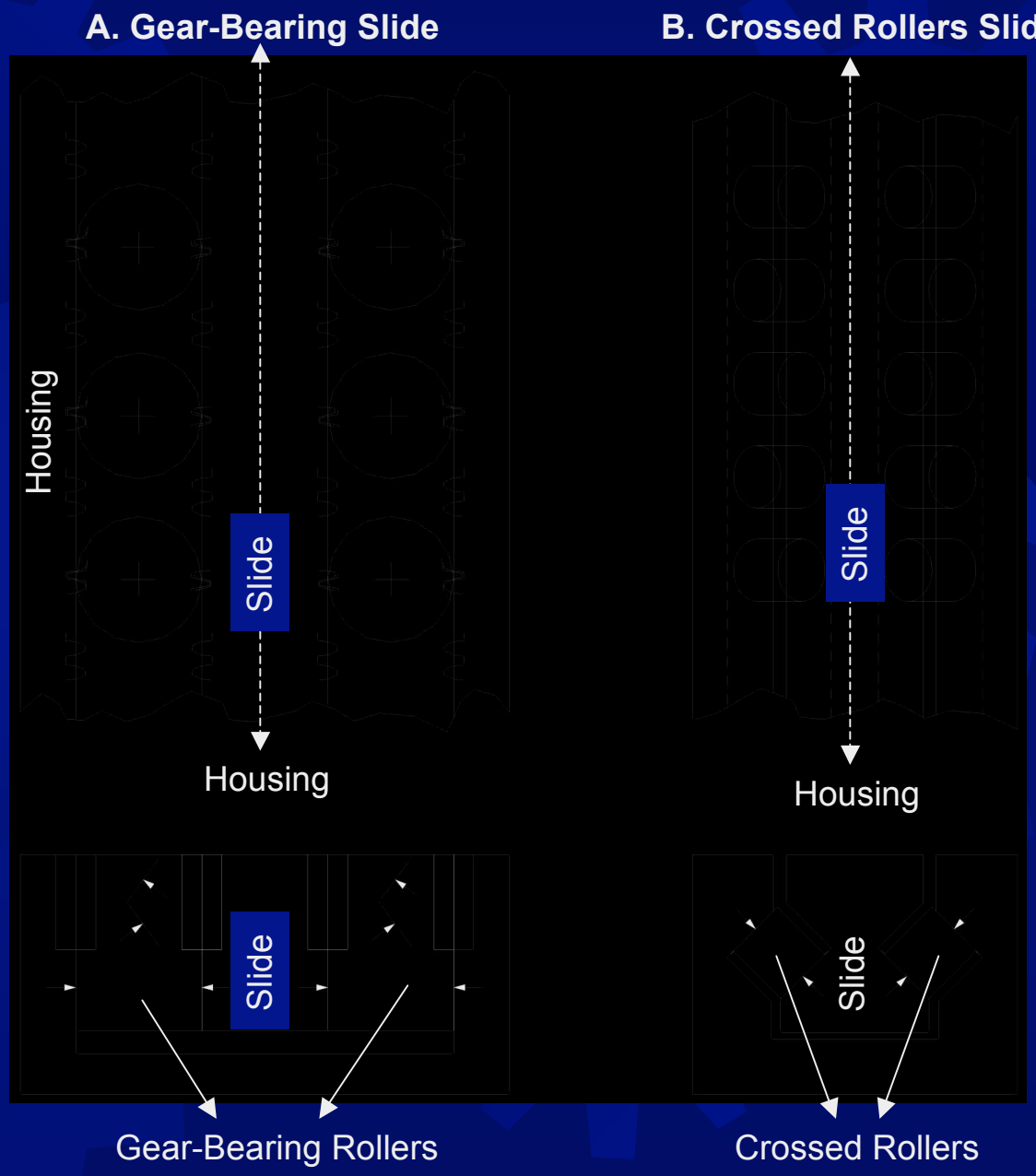
# Half Tooth Mesh Sequence



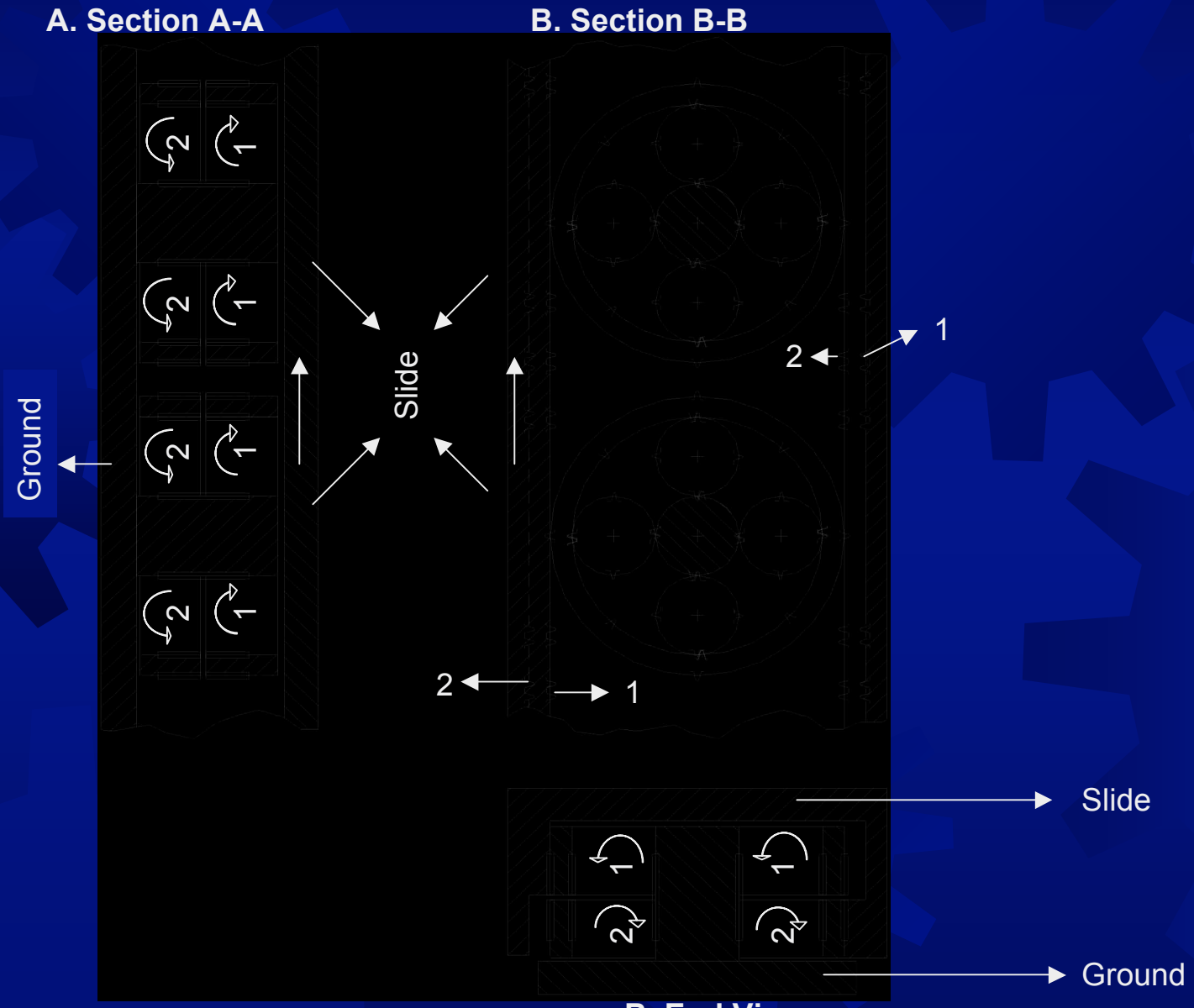
# Half Tooth Planetary Layout



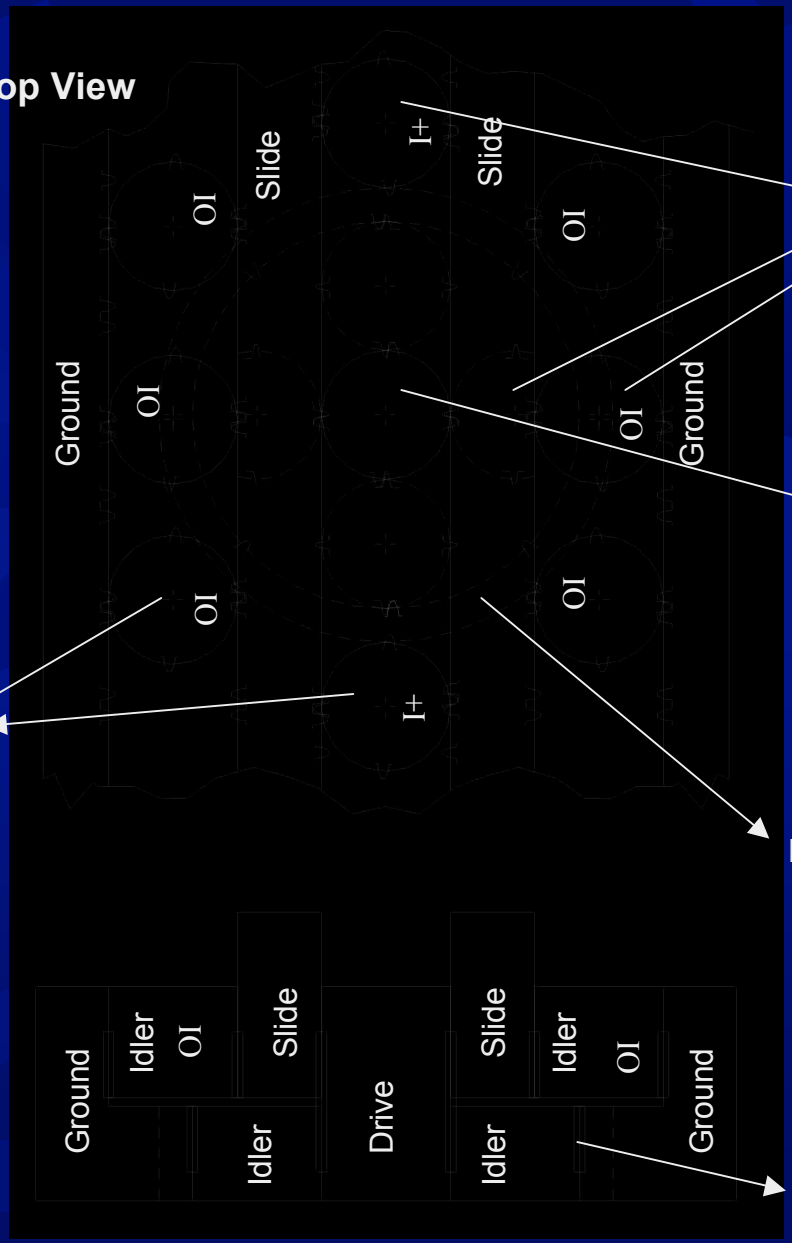
# Basic Linear Slides



# Long Stroke Linear Slides



# Direction Reversing Linear Slides



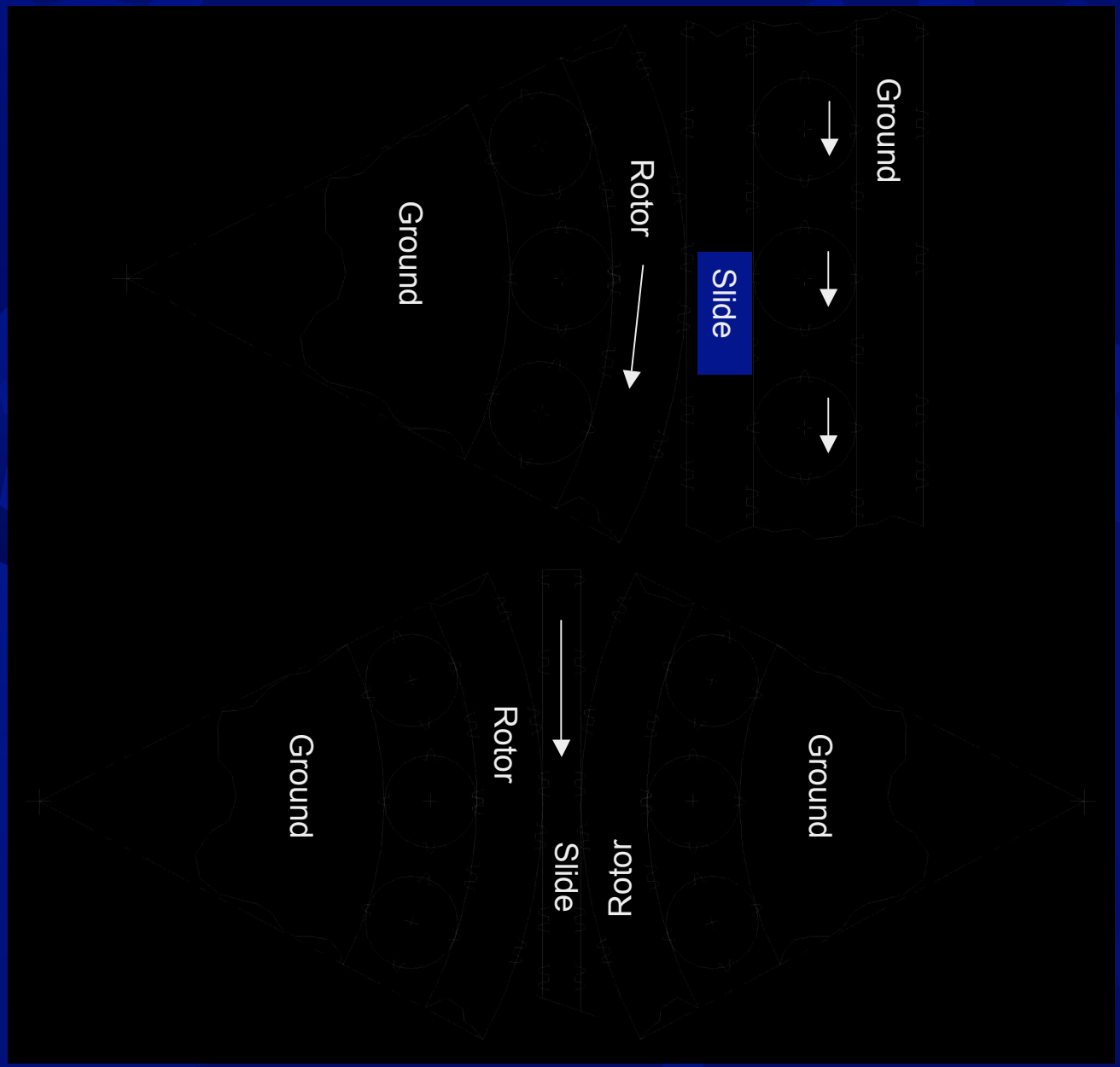

All other rolling members are identical, simple gear-bearing rollers

Drive Compound Gear-Bearing Roller

OI & I Idlers same as height

Ring is part of ground

# Linear to Rotary Motion Conversion



# Gear-Bearing Operational Characteristics

## BEARING FUNCTION SMOOTHNESS

- GEAR-BEARINGS ROTATE AND ORBIT BY POSITIVE GEAR ACTION (BEARINGS BY TRACTION DRIVE SUBJECT TO MICRO-CHATTER)
- GEAR-BEARINGS INHERENTLY MAINTAIN SPACING (BEARINGS REQUIRE A CARRIER, WHICH SLIDES, CATCHES AND ADDS TO CHATTER)
- GEAR-BEARING GEAR AND BEARING FUNCTIONS MOVE TOGETHER SYNCHRONOUSLY SO MECHANICAL NOISE IS COHERENT AND LESS NOTICEABLE. (BEARINGS MOVE MORE RANDOMLY AND THE NOISE IS INCOHERENT AND MORE NOTICEABLE).

# Gear-Bearing Operational Characteristics (continued)

PRECISION OF MOTION

- GEAR-BEARING COMPONENTS INTERFACE DIRECTLY TO EACH OTHER AND TEND TO CENTER UP DURING OPERATION. (SEPARATE BEARINGS AND GEARS HAVE INTERMEDIATE MEMBERS, SUCH AS INNER RACES, THAT ADD EXTRA CONSTRAINTS AND CAUSE MICRO-WOBBLE).
- CONTACT FRICTION LOCATION IN GEAR-BEARINGS ADDS TRACTION DRIVE TO GEAR ACTION TO MINIMIZE TORQUE DRAG. (BEARING LOCATIONS ARE OFFSET FROM GEAR ACTION SO BEARING FRICTION ADDS PARASITIC TORQUE TO GEAR ACTION).

# Gear-Bearing vs. Present Architecture

- Gear-bearing devices are constructed using gear-bearing components. (Present architecture uses bearing and gear components and intermediate members.)
- Gear-bearing components use gear teeth to transfer mechanical force through devices, to perform thrust-bearing functions and to provide bearing separation. (Present architecture uses gear teeth to transfer mechanical force only.)
- Gear-bearing components use roll surfaces both to perform radial bearing functions and to speed synchronize the multiple contact forces on each component. (Present bearings perform radial and thrust bearing functions. They move asynchronously with respect to gears.)
- Gear-bearing components interface directly to each other and move together in a mutually synchronous manner. Their contact forces act in rolling friction and resist side and thrust loads in true 4-way bearing action. In this manner, entire gear-bearing devices function using the direct interfaces of various gear-bearing components. (Present architecture uses intermediate members in interfacing device gears and bearings. Bearings, gears, intermediate members move asynchronously.)


# Contact Information

For more information about this technology, please contact Darryl Mitchell with NASA Goddard Space Flight Center's Technology Transfer Office at:

Darryl.R.Mitchell@nasa.gov

(301) 286-5169 – phone

(301) 286-0301 – fax